SWINE WASTE MANAGEMENT OPTIONS[1/]

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The trend in swine production is towards total confinement with hogs under roof. However, at present, only about 20 percent of the hogs raised by 10 percent of the hog farmers in the United States are in total confinement systems. The shelter plus open-lot facilities, either paved or dirt/partially paved lots, constitute about 60 percent of the total systems. The remaining 30 percent of facilities are pasture with portable shelters.

The major environmental problems with swine production facilities are runoff from open lots, runoff from manure covered cropland, and odors. Estimates are that about 112,000 farms, or over 20 percent of the hog farms, have runoff problems. Of those lots with runoff control problems, open-lot systems constitute 77 percent, pasture systems 18 percent, and confinement systems 5 percent. Improper management of surface spreading takes place on many operations, and runoff results. Also, odor nuisances occur with a large number of swine facilities.

The purpose of this discussion is to describe and evaluate alternative systems and/or technologies currently used to handle wastes from livestock facilities of less than 1000 animal units. The systems are evaluated with regard to controlling water pollution and odor nuisance. Also, an economic analysis of alternative waste management systems for swine facilities is provided.

Swine waste management options consider the two phases of production, the breeding or production of feeder pigs and the feeding. The first includes farrowing, nursery, gestating sows and boars. The feeding operation begins when the pigs are about 40 to 50 lbs and ends when the market weight is about 220 lbs.

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WASTE SYSTEMS

Partial housing is frequently used for small breeding operations. Either portable housing rotated to new pastures or paved lots with farrowing houses are common. The portable houses are disinfected and moved to a new pasture between farrowings. Because of the high labor requirements of these types of farrowing, the swine operation is normally small.

The pasture system is depicted in Figure 1. There is no waste handling needed, and the potential for water and odor pollution is low. Capital investment is low in areas with low land prices. Bedding is cleaned out of the farrowing houses before moving them to a new pasture. Stocking rate and site selection are primary factors in avoiding pollution.

There should be a complete grass cover present, and fields with flowing streams, wet spots or grassed waterways must be avoided. In periods of high temperature, shade or provision to ventilate the farrowing houses is needed.

The farrowing house on paved lot system is illustrated in Figure 2. The manure dropped on the lot is normally accumulated until the sow and pigs are removed. Then the lots are scraped, with the manure being handled in the solid form. Rainfall runoff is a potential pollution problem. A settling basin and grass infiltration area (Figure 2) can be used to avoid direct runoff into a waterway. Odor nuisance can be a problem during warm and moist weather conditions and additional scraping of solids on the paved lot may be needed. Capital investment and operating costs generally are higher than the pasture system; however, the pigs produced per litter with the paved lot system are higher than the pasture system.

Totally housed farrowing and nursery facilities are common for swine breeding operations. The trend is mostly to slotted floors for the rear portion of the farrowing crate or pen. Some form of liquid waste handling is used with slotted floor

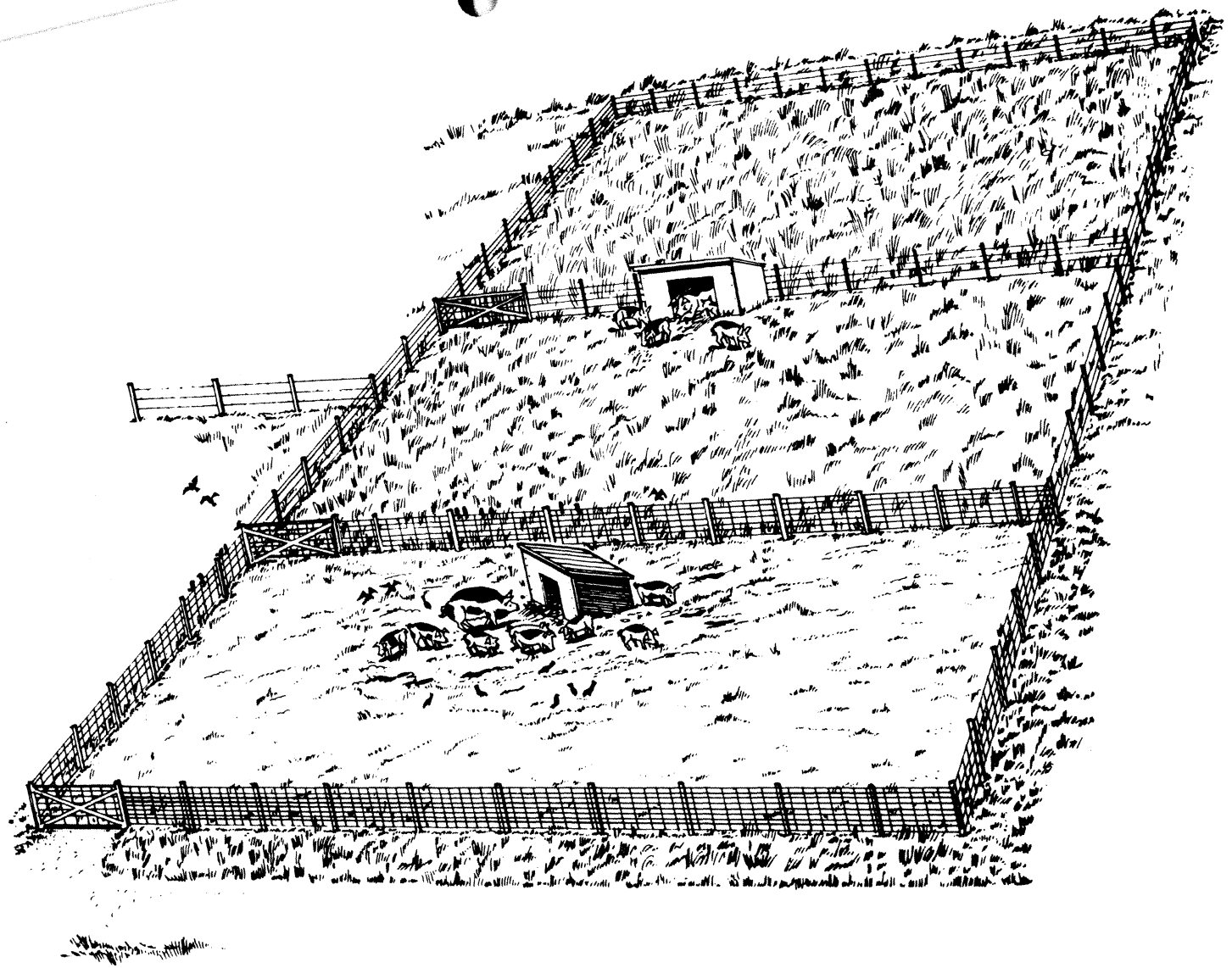

Figure 1. Swine breeding - portable farrowing houses on pasture.

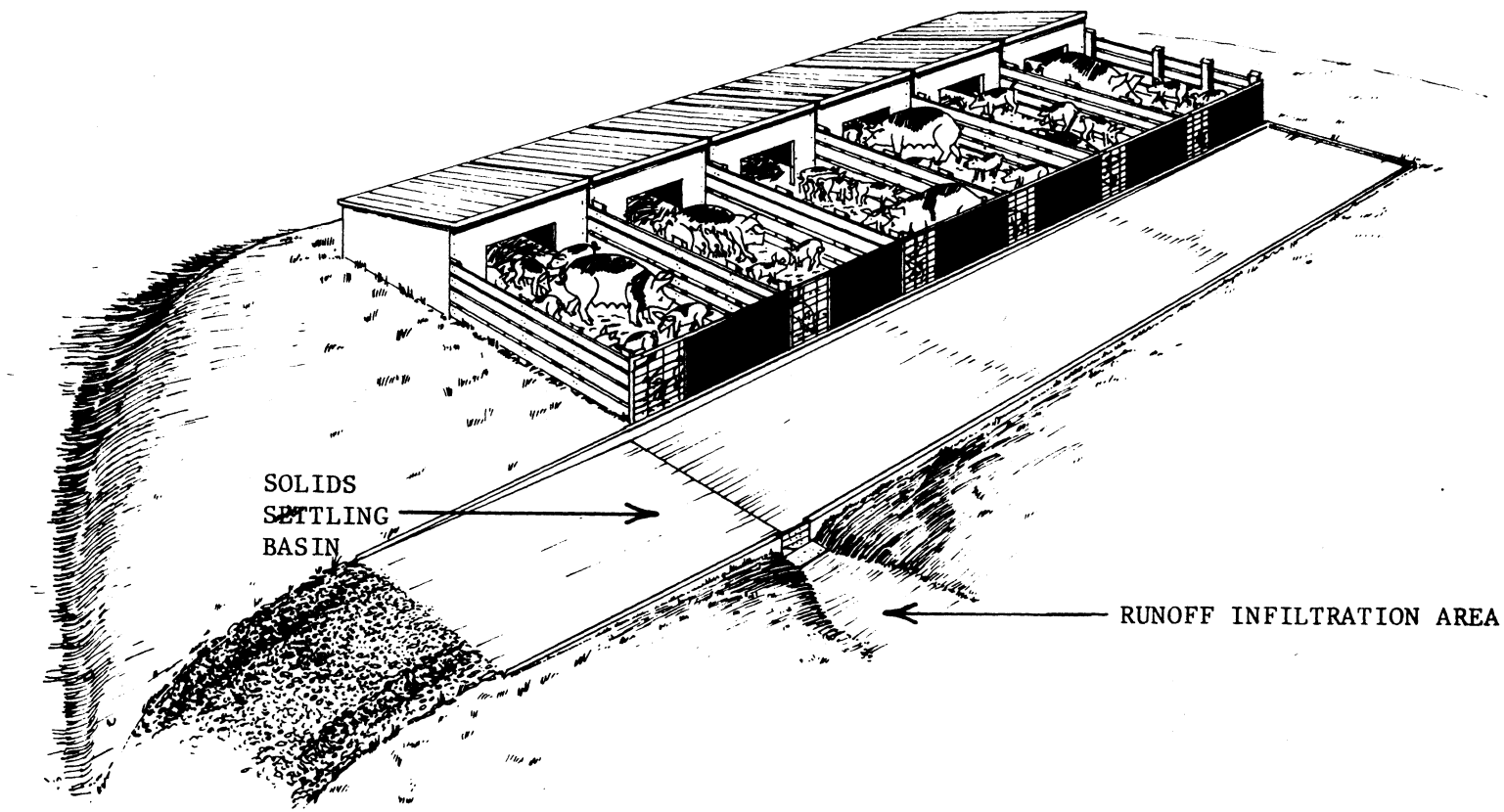

Figure 2. Swine breeding.- Farrowing house is on paved lot. Manure scraped and handled in solid form. Runoff control includes settling basin and grassed infiltration area.

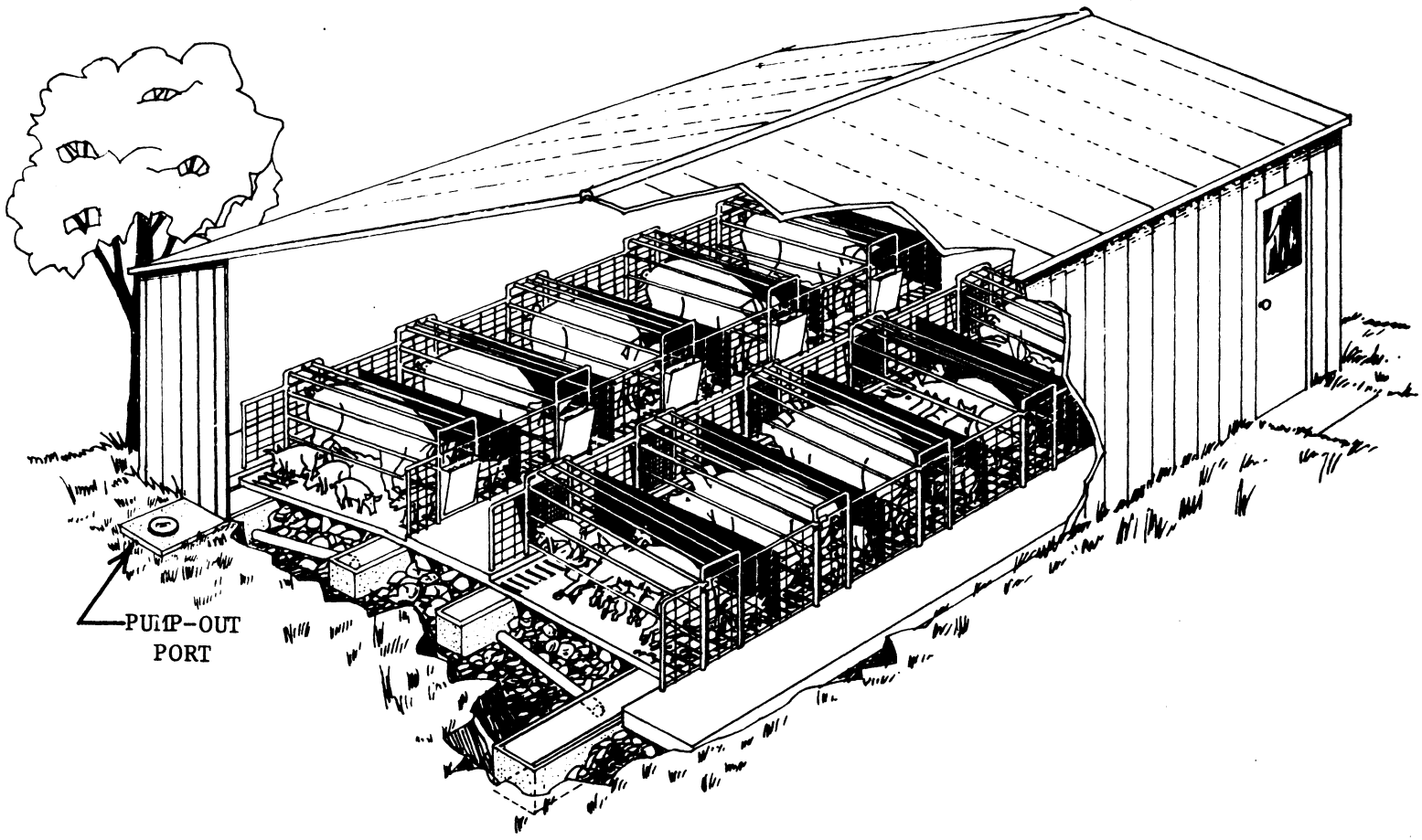

Figure 3. Confined housing, farrowing crates, partially slotted floor, pit storage, liquid handling.

systems. Houses with solid concrete floors are used in many facilities. Solid floors require scraping and manure is usually handled as a solid.

The concept of slotted floors with pit storage for farrowing crates and nursery pigs is shown in Figure 3. A vacuum tank wagon is normally used to pump out the pit. The suction hose is inserted into the pump-out port and pushed to the bottom of the pit. If the pits are pumped empty each time, very little sludge will accumulate in the pits. The distance between pump-out ports is a design constraint. Frequently a few inches of water are placed in the bottom of the pit after each emptying to help control odors.

Variations in handling the waste in slotted floor facilities for farrowing are the "V-trough" pit facility with gravity discharge to outside storage or a "trickle tube" or standpipe with over-flow to an outside storage basin. The waste is stored in the outside structure and then hauled to the field or pumped through an irrigation system to the field. Plastic or rubber linings and covers are commercially available for earthen basin to help control odors. In regions of moisture deficit the trickle tube system can be utilized for many years without any spreading of liquid or solids required. When wastes are flushed from beneath slats to an outside treatment lagoon, an irrigation system is normally used for disposal of effluent. The principal environmental concern of these waste systems is disposing of the waste on cropland. Regional application rates and management factors for the land application of manure to avoid pollution should be used. Odor nuisance should not be a problem if proper application methods and management practices are used.

Three management systems are used for feeding out hogs: pasture, open-lot, and total confinement.

Pasturing of fed hogs is practiced through much of the humid areas. A recommended loading is 25 or less market hogs per acre. Beyond this density, bare spots begin to appear in the pasture. With rotation of pastures

and/or removing animals during the nongrowing season, larger stocking rates may be used. Lots with 100 or more hogs per acre will not support vegetation. If the stocking density and management system used maintains vegetative cover, no waste handling is needed. It was noted earlier that 18 percent or about 20,000 pasture systems do have potential pollution problems. By avoiding steep slopes, waterways and steams and using proper pasture management, runoff problems can be minimized.

Open-lot systems for fed hogs can be divided into two categories: totally or partially paved and unpaved. In cool and cold humid areas, housing is provided with the open lot. In the warm and hot areas, housing may not be provided, but shade is essential. (Regions are depicted in Figure 13.)

Paved lot units for fed hogs typically allow 6 sq ft of shelter and 6 to 20 sq ft of open lot per animal. The solid waste is scraped periodically and spread on cropland. Runoff from the paved lot has high pollutant levels and needs to be managed to avoid polluting surface waters. This type of system and alternative methods of handling the runoff are shown in Figure 4. For swine facilities in the humid areas, the settling basin and grass infiltration area may be the best choice. For large facilities the detention basin with cropland irrigation may be a better choice. For facilities in dry or arid climates, the detention pond with cropland irrigation is commonly used to avoid pollution.

Unpaved or partially paved (feeding pad) units allow 6 sq ft of shelter per animal and widely varying lot densities. These lots do not support vegetative cover. In lots with higher densities, any manure buildup is generally scraped and spread on cropland so that manure packs characterisitc of high density beef do not occur. Runoff needs to be controlled as discussed for paved lots. Water infiltrating into the soil can be high in nitrogen, particularly at medium densities (25 to 100 animals/ acre).

Total confinement systems may be divided into two major categories: slotted floor

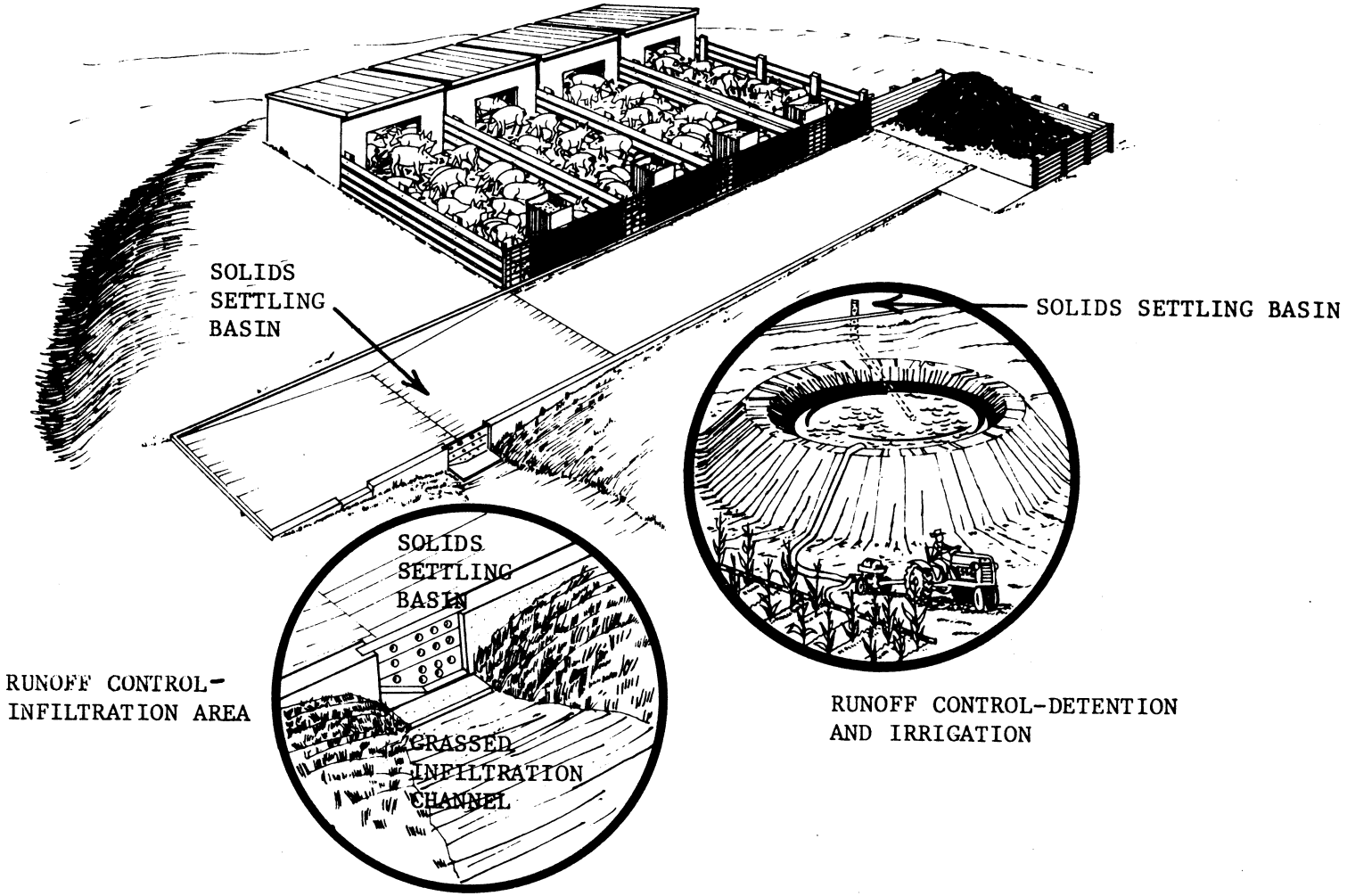

Figure 4. Fed hogs - paved lot with shelter, solid manure handling. Inserts show alternatives for runoff control.

with pit storage and solid floor with discharge to outside storage or treatment. Liquid handling characterizes total confinement facilities.

A partially slotted floor with a pit beneath the slats is shown in Figure 5. The area slatted may range from total to about 1/3 of the pen area. Pens less than 1/3 slatted tend to be very dirty and need hand scraping. With proper pen design and managment practices, pigs will void their waste on the slatted area. The depth of the pits varies to provide desired storage time. In some cases, additional outside storage is provided. The swine waste stored in the pit is commonly spread on cropland, using a vacuum tank wagon. Withdrawing waste from the ports properly spaced along the length of the pit removes most of the solid, and sludge buildup does not occur.

There are two types of solid concrete floor facilities with discharge to outside storage or treatment. The narrow-gutter system with outside storage is shown in Figure 6. The accumulated wastes in the gutter (several days quantity) is released manually to flow by gravity to the storage tank. Frequently, storage is provided in a concrete tank, although earthen storage basins may be used.

The other solid floor system incorporates a shallow channel which is flushed periodically, every 1 to 4 hours. The flushing water transports the waste to an outside treatment unit. Usually the treatment unit is an anaerobic lagoon system. A two-stage lagoon system in common, shown in Figure 7. Lagoon water is normally recycled for flushing from the second lagoon. For the anaerobic lagoon(s) to function with minimumodor, dilution water from well, roofs or surface runoff is needed. Therefore, provision for irritating lagoon wastewater on cropland is needed. Design criteria and management requirements for anaerobic lagoons can be found in the Livestock Waste Facilities Handbook, MWPS-18, Midwest Plan Service.

Capital requirements tend to be high for total confinement systems; however, their operating costs are less than those of the open-lot or pasture system.

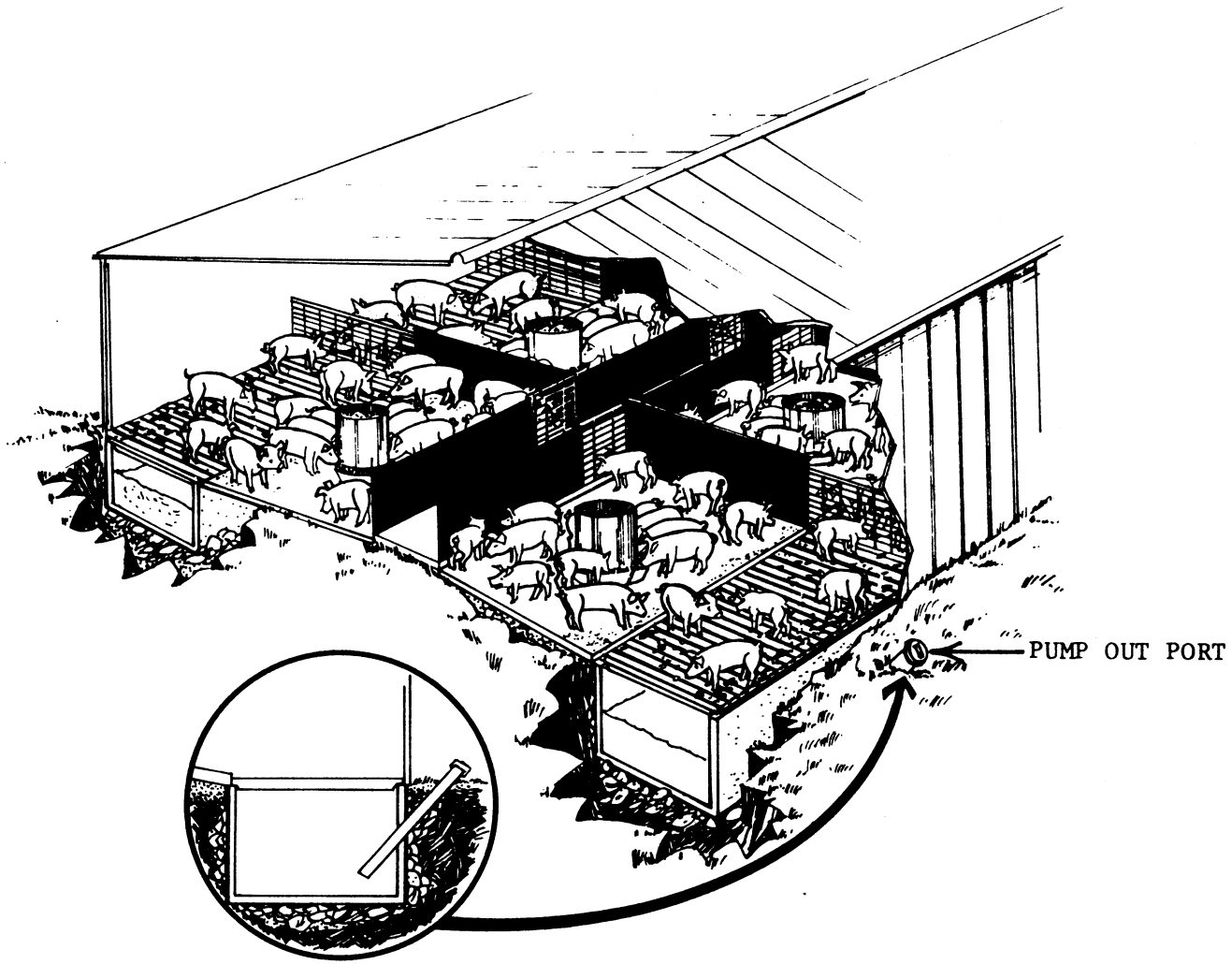

Figure 5. Fed hogs - confined, partially slotted floors, pit storage, liquid handling.

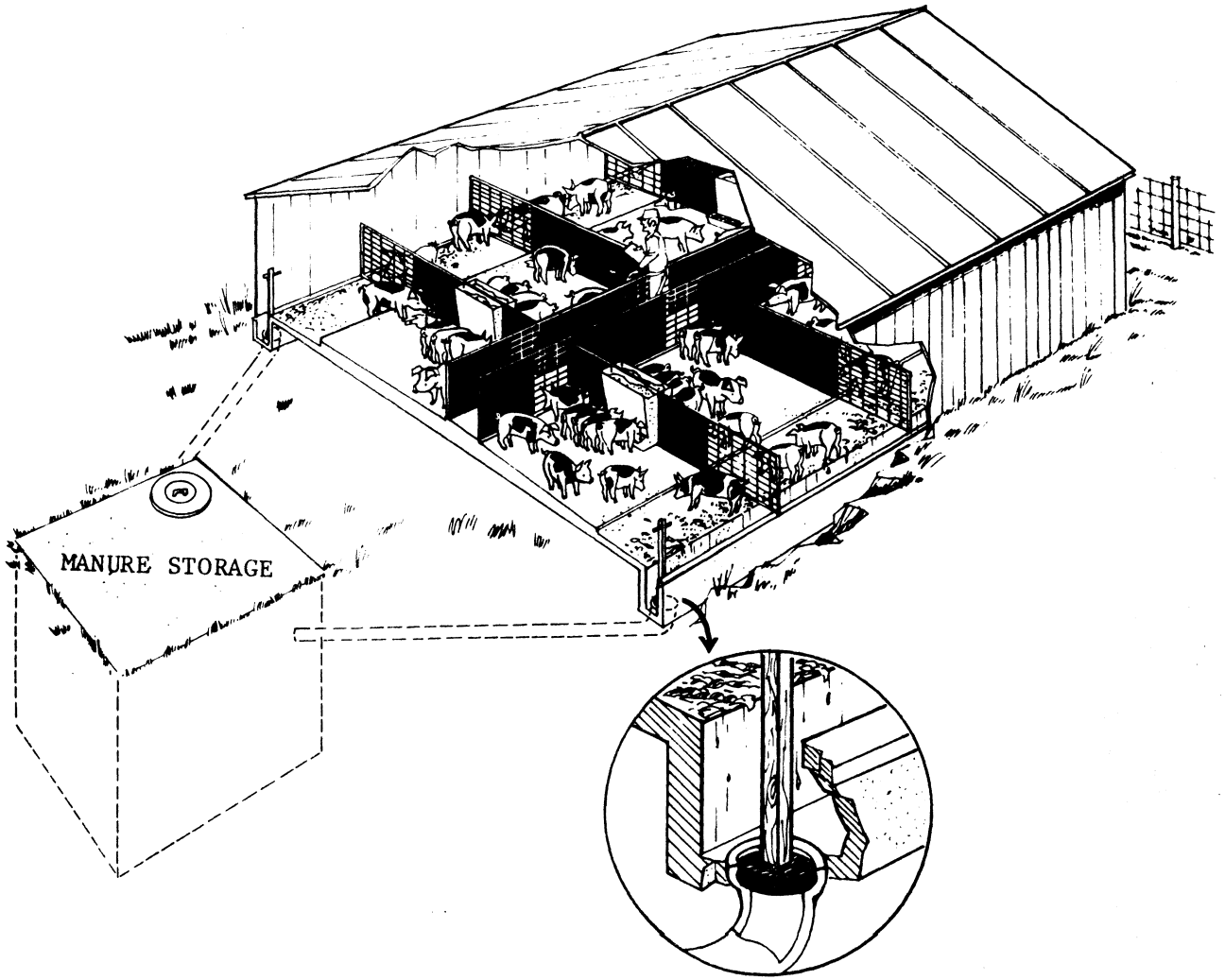

Figure 6. Fed hogs - confined, concrete floor, narrow gutter, outside storage, liquid handling.

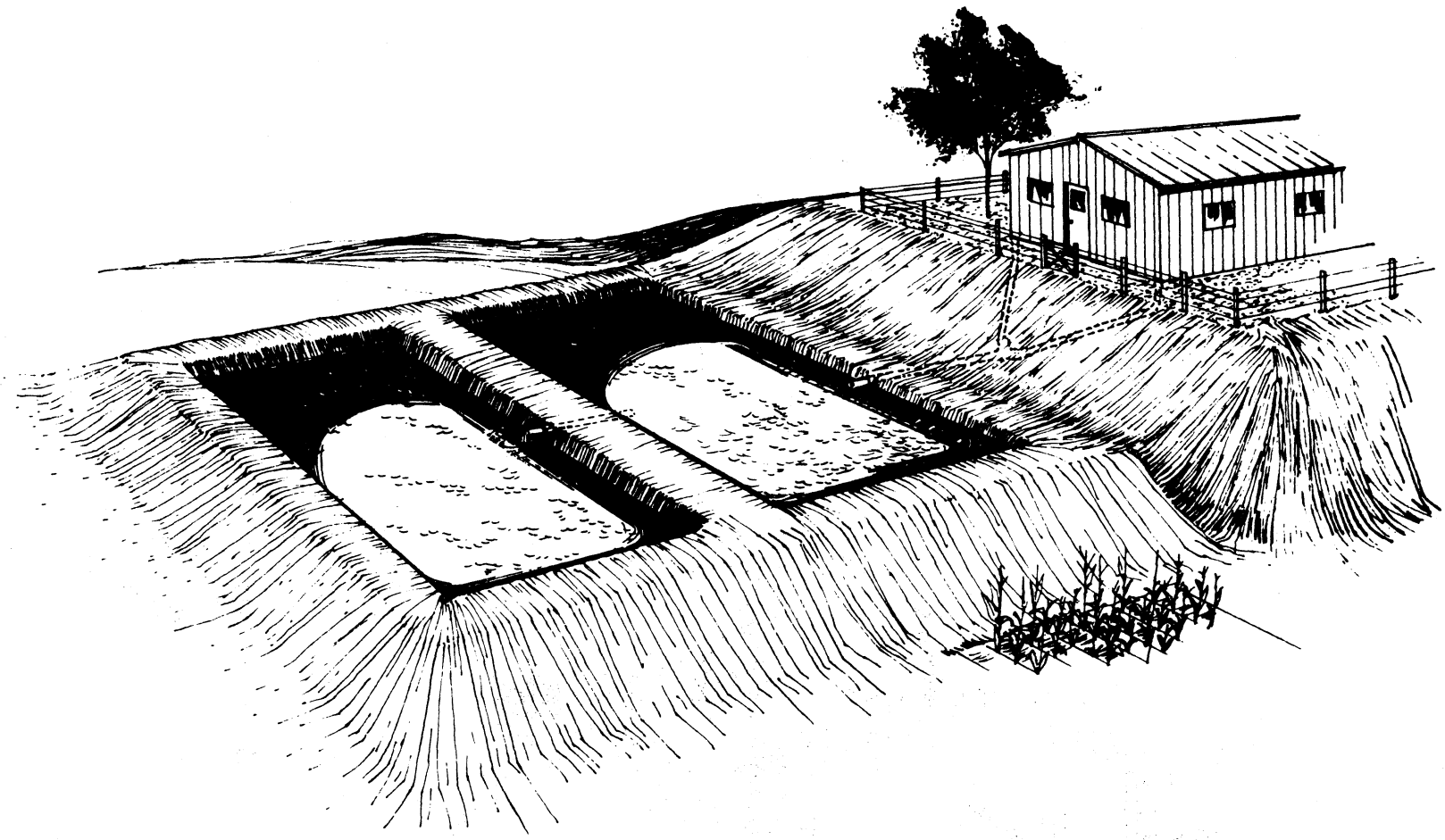

Figure 7. Two-stage anaerobic lagoon system for treatment of wastes flushed from swine building.

For swine operations located on productive cropland, open-lot and total confinement systems are preferred due to their low land requirements.

With confinenment systems come more disease control problems. Generally the level of management must be much higher with confinement systems in order to control disease and control odor and runoff.

ECONOMIC ANALYSIS

The following analysis of swine waste management systems includes an estimate of returns and costs for alternative systems. Also, qualitative estimates of society costs are made in terms of water and air quality.

Benefits from Waste

Nitrogen, phosphate and potash availabilities depend on the type of swine waste management system (Table 1). Generally, those systems scraping and loading solid manure from an exposed lot surface have more nutrient losses than those systems where liquid manure is stored. Immediate soil incorporation by injection reduces nutrient losses substantially. On the other hand, a flush system using a lagoon for storage and treatment substantially increases nutrient losses.

Manure production is variable and depends on the ration, weight of the hog, and climate. It is assumed that a fed hog averages 135 pounds on the lot and produces an average of 15 pounds of nitrogen, 17 pounds of phosphate (P_2O_5), and 18 pounds of potash (K_2O) per year. The breeding herd during gestating, farrowing and nursing is assumed to weigh an average of 304 pounds per animal unit. This animal unit produces an average of 40 pounds of nitrogen, 14 pounds of phosphate and 26 pounds of potash per year.

After computing losses due to storage, handling and spreading (Table 1), returns to nutrients are computed by pricing the available nitrogen at $0.16, phosphate at $0.18, and potash at $0.10 per pound. Two sets of assumptions are used concerning the returns to nutrients: one set uses 100 percent utilization of available nutrients, and the other uses 50 percent utilization.

TABLE 1. NITROGEN, PHOSPHATE (P_2O_5), AND POTASH (K_2O) AVAILABLE TO CROPS FROM SWINE WASTE PER ANIMAL UNIT[a] FOR ALTERNATIVE HANDLING SYSTEMS.

System	Nutrients Available to Crops per Animal Unit[b] (lb/yr)		
	Nitrogen	Phosphate (P_2O_5)	Potash (K_2O)
Fed Swine			
Pasture, portable shelter	11	17	18
Unpaved lot, shelter, solid handling	5	8	11
Paved lot, shelter, solid handling	7	12	13
Total shelter, slotted floor, pit, liquid handling	8	15	16
Total shelter, concrete floor, flush lagoon, irrigate	2	8	11
Total shelter, concrete floor, narrow gutter, storage	8	15	16
Total shelter, slotted floor, pit, liquid, soil incorporated	11	17	18
Total shelter, concrete floor, narrow gutter, storage, soil incorporation	11	17	18
Swine Breeding			
Pasture, portable shelter	30	14	16
Paved lot, shelter, solid handling	19	10	20
Total shelter, concrete floor, pen/crate, solid handling	24	13	23
Total shelter, slotted floor, pit, liquid handling	22	13	23
Total shelter, slotted floor, flush, lagoon, irrigate	6	7	16
Total shelter, slotted floor, pit, liquid, soil incorporation	28	14	26

[a]One animal unit: fed hog = 135 lb, swine breeding = 304 lb (sow and litter = 375 lb, gestating sow = 275 lb)

[b]Nutrient production per year:

		N (lbs)	P_2O_5 (lbs)	K_2O (lbs)
Fed swine (135 lb feeder)		15	17	18
Swine breeding		40	14	26
sow with litter (2/7 of year)	24	8	16	
gestating sow (5/7 of year)	16	6	10	

Analysis of Options

Fed Swine, Paved Lot--

Annual net system costs for this system are shown in Table 2. The basic system results in the lowest annual net system costs, with grass infiltation and detention irrigation systems producing higher costs at each size level. These costs are depicted in Figure 7.

Between swine feedlot capacities of 200 and 1000 head, few economies of size are gained. Thus, the investment outlays in equipment such as spreaders, loaders, and scrapers result in lot capacities of less than 200 head being at a relative disadvantage.

The 50 head capacity system is at a distinct disadvantage under any of the pollution control alternatives. The paved lot system with no runoff control results in annual net system costs of $16.92 per animal year as seen in Table 2. With a 2.5 turnover rate, waste disposal costs per pig sold are $6.77. When the grass infiltration area is added, annual net system costs per animal year increase by $1.67. If the detention basin/irrigation system is used costs per animal year increase by $11.10.

Annual net system costs per animal year for the 1000 head capacity paved lot with no pollution are approximately $1, and additions of grass infiltration or detention/irrigation increase these costs by less than $1 per animal year.

Fed Swine, Unpaved Lot--

The annual net system costs per animal year for the unpaved lot systems are similar to those for the paved lot systems. Again, substantial economies of size are enjoyed by the moderate to large sized lots due to the lumpiness of the initial investment as shown in Figure 8. Also, the added costs of pollution control are minimal for the grass infiltration system.

For the 50 head capacity lot, costs of the basic system are $13.21 per animal year (Table 3). With the addition of the grass infiltration method of runoff control, costs per animal year increase by $0.90 to $14.11. If the detention/irrigation system is used to control runoff, costs per animal year jump by $12.05 to $25.26.

Comparing these costs for the 50 head capacity lot with those for the 600 or 1000 head capacity lot, economies of size in the detention/irrigation system are noticeable. For the 600 head lot using detention/irrigation, costs per animal unit are $2.33, and costs for the 1000 head lot using detention/irrigation are only $1.41 per animal unit. Thus, if this system were imposed on all lots the larger producer would have a distinct competitive advantage.

On the other hand, the grass infiltration system presents fewer disadvantages to the small producer. The addition of grass infiltration systems increases costs per animal year by $0.90, $0.50, $0.31, and $0.27 for the 50, 200, 600 and 1000 head capacity lots, respectively.

Fed Swine, Unpaved Lot Without Shelter--

Limited to warm and hot humid regions of the country, this waste management system requires only small investment outlays. The only initial investment and annual costs of waste management are for land. With land area being 250 sq ft per fed hog, the initial investment is computed at $215 per head capacity, which results in annual costs of $0.47 per animal year.

Due to the large surface area of the lot, using the detention/irrigation system would require massive detention basin volume and result in high initial capital investments. Thus, only the grass infiltration system is considered. For example, with the addition of grass infiltration on the 600 head lot, costs per animal year increase from $0.47 on the basic system to $0.85 (Table 4).

Fed Swine, Total Slats, 6 Month Pit Storage--

Confined feeding operations are increasing in numbers throughout all humid regions. The types of systems are numerous; however, only the predominant types are discussed. One of the more typical confinement systems is the slotted floor construction with a pit beneath the slats. Waste is stored and then hauled to the field by tank wagon to be spread or injected. This system is analyzed using 200, 600, and 1000 head herd sizes and results are shown in Table 5 and Figure 9. Net system costs total $5.84 per animal year for the 200 head capacity lot using surface spreading. These per animal unit costs decline for the larger slotted floor systems using surface spreading to $2.04 and $1.32 per animal year for the 600 and 1000 head capacity lots.

Incorporating the waste by injection is a modification to the slotted floor system. As the investment in injection equipment is nearly the same for the 200 head lot as the 1000 head lot, economies of size are realized. In addition, injecting the waste makes more of the nitrogen available for crops. Thus, for the larger lot sizes, injection actually costs less than surface spreading. Net system costs per animal year on the 1000 head capacity lot using injection are only $0.69, and this is $0.63 per animal year less than the cost for surface spreading.

Fed Swine, Solid Floor, Flush Shallow Channel to Lagoon--

Another common confinement system is the solid floor flush channel system. Manure accumulates in a shallow gutter and is removed by flushing to a lagoon. Irrigation equipment is used to spread the treated wastewater on nearby fields. Net system costs range from $5.65 per animal year for the 200 head facility to $2.72 for the 1000 head facility (Table 5 and Figure 10), and these compare favorably with the costs of other confinement systems.

Fed Swine, Solid Floor, Narrow Gutter, Storage Basin--

The lowest cost waste management system for fed hogs in confinement appears

to be this system. Gravity moves the accumulated waste from a narrow gutter to a storage basin upon manually opening of the valve. A tank wagon is used to transport the waste to the field where it is either spread or injected.

For the larger herd sizes, this system actually produces a small return. On the 600 head capacity lot using surface spreading, net system returns are $0.55 per animal year, and on the 1000 head capacity lot net returns are $1.63 per animal year (Table 5).

Injecting waste improves returns on the larger lots even when a larger initial investment is required. Net system returns are $0.89 per animal year for the 600 head capacity lot, or $0.34 per animal year higher than surface spreading.

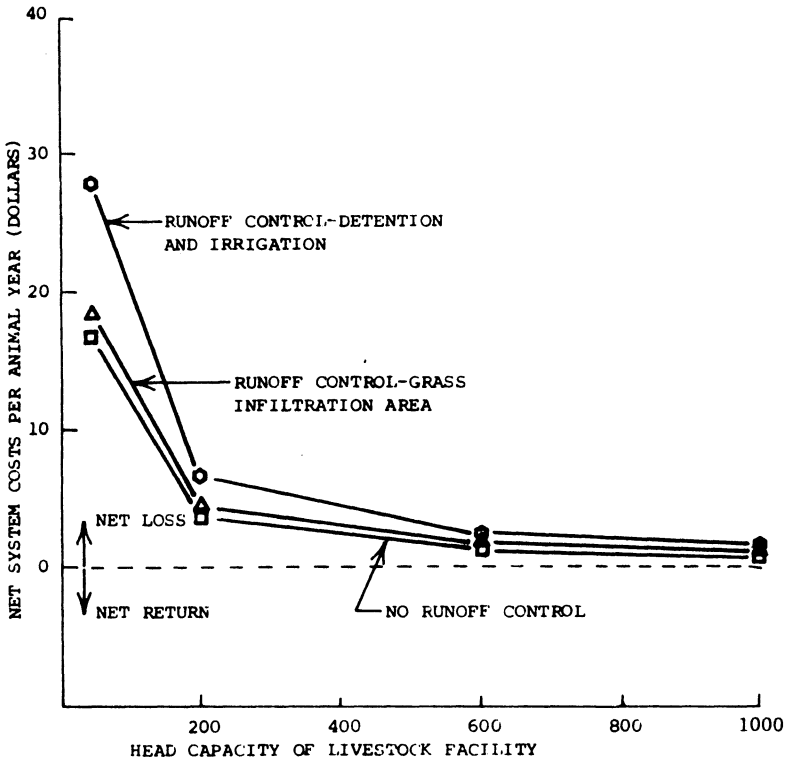

Figure 7. Fed swine, annual net system costs for paved lot with shelter (100% utilization of available nutrients assumed).

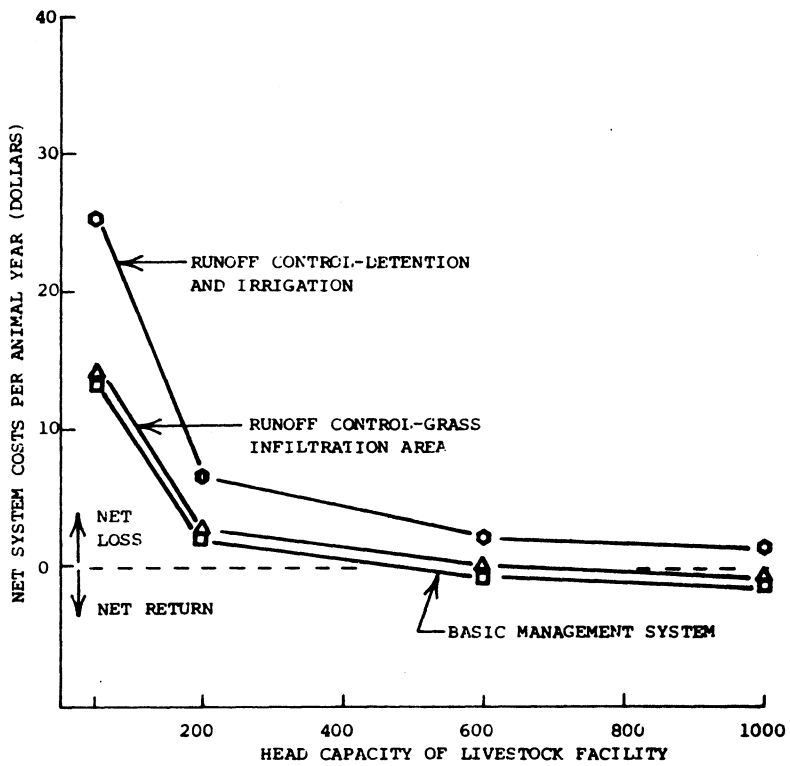

Figure 8. Fed swine, annual net system costs for unpaved lot with shelter (100% utilization of available nutrients assumed).

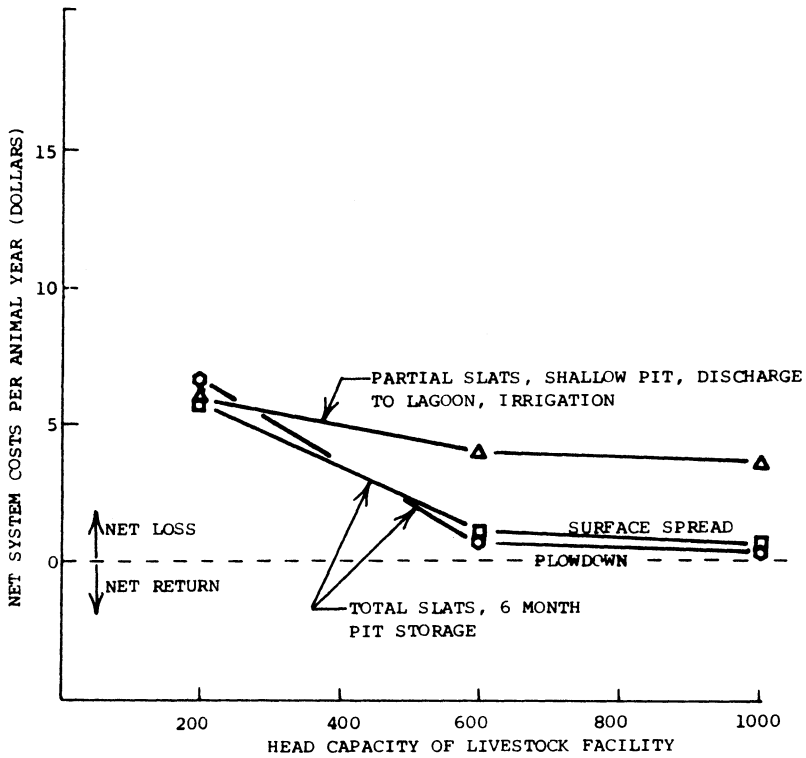

Figure 9. Fed swine, annual net system costs for total slats with pit storage, and partial slats discharging to lagoon (100% utilization of available nutrients assumed).

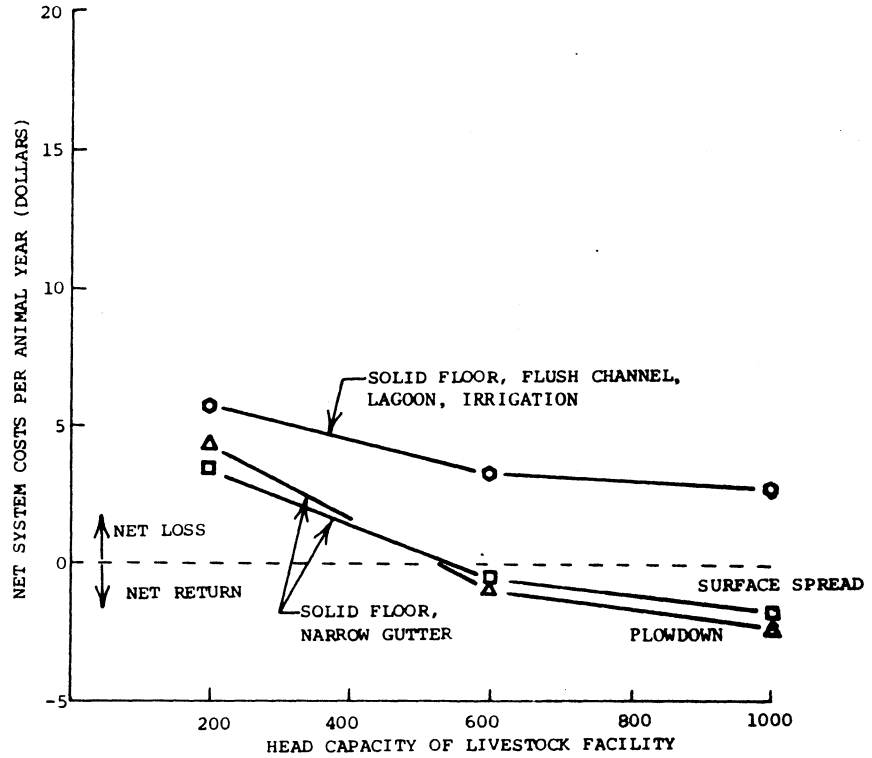

Figure 10. Fed swine, annual net system costs for solid floor with flush channel and solid floor with narrow gutter discharge to storage basin (100% utilization of available nutrients assumed).

Table 2. FED HOGS, PAVED LOT WITH SHELTER, NET SYSTEM RETURNS AND LEVEL OF POLLUTANTS FOR ALTERNATIVE WASTE MANAGEMENT SYSTEMS

Waste Management System	System Modification	Herd Size (Head Capacity)	Net System Return		Level of Pollution[a]		
			At 50 Percent Usage of Nutrients	At 100 Percent Usage of Nutrients	Water		Odor
					Quantity of Runoff	Quality of Runoff	
			(Dollars per Animal Year)		(Pollution Scale)[a]		
Pave lot with shelter[b]	Base	50	-19.21	-16.92	4	5	4
	Runoff control-detention/ irrigation	50	-30.31	-28.02	1	1	4
	Runoff control-grass infiltration	50	-20.88	-18.59	1	1	4
	Base	200	- 6.17	- 3.88	4	5	4
	Runoff control-detention/ irrigation	200	- 9.15	- 6.86	1	1	4
	Runoff control-grass infiltration	200	- 6.73	- 4.44	1	1	4
	Base	600	- 3.55	- 1.26	4	5	4
	Runoff control-detention/ irrigation	600	- 4.58	- 2.29	1	1	4
	Runoff control-grass infiltration	600	- 3.81	- 1.52	1	1	4
	Base	1000	- 3.14	- 0.85	4	5	4
	Runoff control-detention/ irrigation	1000	- 3.83	- 1.54	1	1	4
	Runoff control-grass infiltration	1000	- 3.36	- 1.07	1	1	4

[a]Scale: 1 (No Pollution) 2 3 4 5 (Severe Pollution)

[b]Cold humid, cool humid, warm humid, and hot humid regions (Figure 13).

Table 3. FED SWINE, UNPAVED LOT WITH SHELTER, NET SYSTEM RETURNS AND LEVEL OF POLLUTANTS FOR ALTERNATIVE WASTE MANAGEMENT SYSTEMS

Waste Management System	System Modification	Herd Size (Head Capacity)	Net System Return		Level of Pollution[a]		
			At 50 Percent Usage of Nutrients	At 100 Percent Usage of Nutrients	Water: Quantity of Runoff	Water: Quality of Runoff	Odor
			(Dollars per Animal Year)		(Pollution Scale)[a]		
Unpaved lot with shelter[b]	Base	50	-14.38	-13.21	5	5	3
	Runoff control-detention/ irrigation	50	-26.43	-25.26	1	1	3
	Runoff control-grass infil-tration	50	-15.28	-14.11	1	1	3
	Base	200	- 3.21	- 2.04	5	5	3
	Runoff control-detention/ irrigation	200	- 7.96	- 6.79	1	1	3
	Runoff control-grass infil-tration	200	- 3.71	- 2.54	1	1	3
	Base	600	- 0.74	+ 0.43	5	5	3
	Runoff control-detention/ irrigation	600	- 3.50	- 2.33	1	1	3
	Runoff control-grass infil-tration	600	- 1.05	+ 0.12	1	1	3
	Base	1000	-00.13	+ 1.04	5	5	3
	Runoff control-detention/ irrigation	1000	- 2.58	- 1.41	1	1	3
	Runoff control-grass infil-tration	1000	-0.40	+ 0.77	1	1	3

[a]Scale: 1 (No Pollution) 2 3 4 5 (Severe Pollution)

[b]Cold humid, cool humid, warm humid and hot humid regions (Figure 13).

Table 4. FED SWINE, UNPAVED LOT WITHOUT SHELTER, NET SYSTEM RETURNS AND LEVEL OF POLLUTANTS FOR ALTERNATIVE WASTE MANAGEMENT SYSTEMS

Waste Management System	System Modification	Herd Size (Head Capacity)	Net System Return		Level of Pollution[a]		
			At 50 Percent Usage of Nutrients	At 100 Percent Usage of Nutrients	Water		Odor
					Quantity of Runoff	Quality of Runoff	
			(Dollars per Animal Year)		(Pollution Scale)[a]		
Unpaved lot without shelter[b]	Base	50	-0.47	-0.47	5	5	2
	Runoff control-detention/ irrigation	50	-0.95	-0.95	2	2	2
	Base	200	-0.47	-0.47	5	5	2
	Runoff control-detention/ irrigation	200	-0.88	-0.88	2	2	2
	Base	600	-0.47	-0.47	5	5	2
	Runoff control-detention/ irrigation	600	-0.85	-0.85	2	2	2
	Base	1000	-0.47	-0.47	5	5	2
	Runoff control-detention/ irrigation	1000	-0.85	-0.85	2	2	2

[a]Scale: 1 (No Pollution) 2 3 4 5 (Severe Pollution)

[b]Warm humid and hot humid regions (Figure 13).

Table 5. FED SWINE, TOTAL SHELTER, NET SYSTEM RETURNS AND LEVEL OF POLLUTANTS FOR ALTERNATIVE WASTE MANAGEMENT SYSTEMS

Waste Management System	System Modification	Herd Size (Head Capacity)	Net System Return: At 50 Percent Usage of Nutrients	Net System Return: At 100 Percent Usage of Nutrients	Level of Pollution[a]: Water: Quantity of Runoff	Level of Pollution[a]: Water: Quality of Runoff	Level of Pollution[a]: Odor
			(Dollars per Animal Year)		(Pollution Scale)[a]		
Total slats, 6 month pit storage[b]	Surface spread	200	-8.63	-5.84	2	2	5
	Injection	200	-9.97	-6.66	1	1	2
	Surface spread	600	-4.83	-2.04	2	2	5
	Injection	600	-4.95	-1.64	1	1	2
	Surface spread	1000	-4.11	-1.32	2	2	5
	Plowdown	1000	-4.00	-0.69	1	1	2
Partial slats, shallow pit, discharge to lagoon[c]	Base	200	-7.33	-5.90	2	2	3
	Base	600	-5.44	-4.01	2	2	3
	Base	1000	-5.07	-3.64	2	2	3
Solid floor, flush gutter to lagoon[d]	Base	200	-7.08	-5.65	2	2	3
	Base	600	-4.65	-3.22	2	2	3
	Base	1000	-4.15	-2.72	2	2	3
Solid floor, narrow gutter discharge to storage basin[e]	Surface spread	200	-6.27	-3.48	2	2	5
	Injection	200	-7.67	-4.36	1	1	1
	Surface spread	600	-2.24	+0.55	2	2	5
	Injection	600	-2.42	+0.89	1	1	1
	Surface spread	1000	-1.16	+1.63	2	2	5
	Injection	1000	-1.05	+2.26	1	1	1

[a]Scale: 1 (No Pollution) 2 3 4 5 (Severe Pollution)

[b]Cold humid, cool humid, warm humid, and hot humid regions (Figure 13).

[c]Warm and hot humid regions.

[d]Cool, warm, and hot humid regions.

[e]Cool and cold regions.

Swine Breeding, Paved Lot with Farrowing House--

The outside paved lot with portable farrowing houses is a low cost alternative for breeding herd waste disposal. Annual net system costs are generally below confinement system costs as seen when comparing Figure 11 and 12. These net costs for various capacities of sows only consider costs and returns of the waste system and do not consider the number of pigs produced per litter for each system; thus, is is only a partial analysis.

Annual net system costs per sow for the 20 head lot are nearly double those for the 50 head lot (Table 6). With no pollution control, the paved lot, farrowing house system for 50 head has net disposal costs of $21.06 per animal year and $43.68 per animal year for the 20 head facility. Further economies of size are gained with the 100 head farrowing unit with net costs dropping to $13.52 per animal unit.

Adding the grass infiltration area increases costs slightly with added costs of $3.49 per animal unit for the 20 head lot to $1.11 per animal unit for the 100 head facility.

Swine Breeding, Total Shelter Systems--

Four total shelter systems are considered, and they include the solid concrete floor with farrowing pens, partial slotted floor with 3 month pit storage beneath the floor, partial slotted floor with shallow pit storage flushed to a lagoon for treatment, and partial slotted floor with waste flushing to a lagoon.

The solid floor farrowing pen system offers relatively low annual net system costs compared to other breeding confinement systems. Net system costs range from $48.80 per animal year to $23.50 per animal year for the 20 and 50 sow units, respectively (Table 6).

Highest waste disposal costs are associated with the partial slotted floor with pit storage (Table 6). Annual net system costs are from $71.70 per animal

unit for 20 sows to $27.11 per animal unit for 100 sows. Unlike most of the other species examined, adding injection increases costs as the increased returns from nutrient availability are small due to the smaller amounts of waste. Added costs for the injection system total $17.47 per animal unit for the 20 sow unit and $3.02 for the 100 sow unit.

The two systems using partial slotted floors with lagoon treatment differ only slightly in terms of their components and net system costs (Table 7). Incorporating the shallow pit into the system is sometimes done in warm humid and hot humid regions. Waste is periodically flushed to a treatment lagoon. With the other lagoon system, regular flushing occurs beneath the slats and requires added investments in a flushing tank and recycle pump.

Annual net system costs are $42.67 per animal unit for the 20 sow capacity facility using shallow pit storage with lagoon treatment. For the system using flushing to a treatment lagoon, annual net system costs are $50.56 per animal unit for the 20 sow capacity facility. These per animal unit costs on the 100 sow capacity facility decline to $16.90 and $19.24 for the shallow pit storage and flushing systems, respectively (Figure 12).

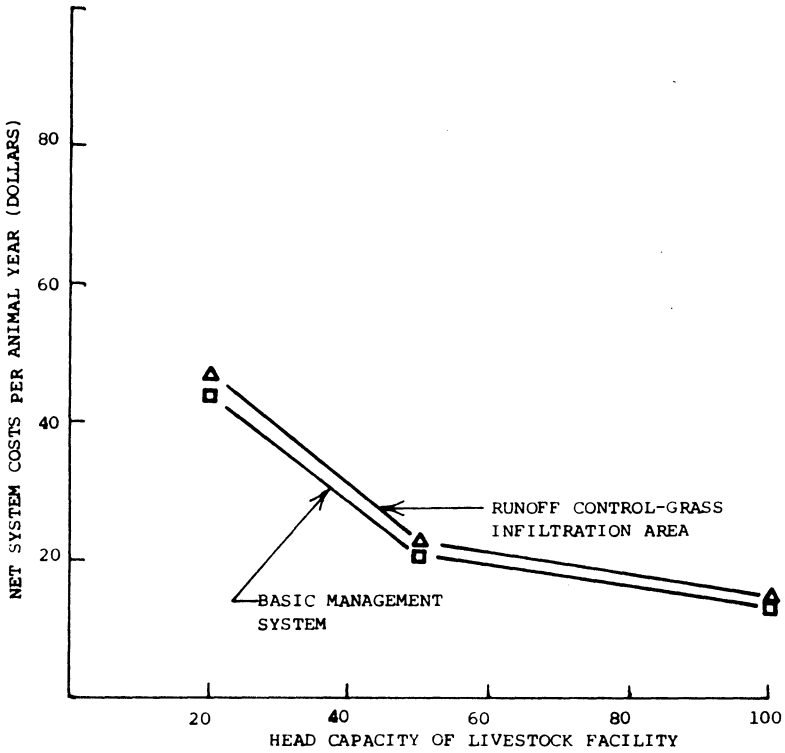

Figure 11. Swine breeding, annual net system costs for paved lot with farrowing house (100% utilization of available nutrients assumed).

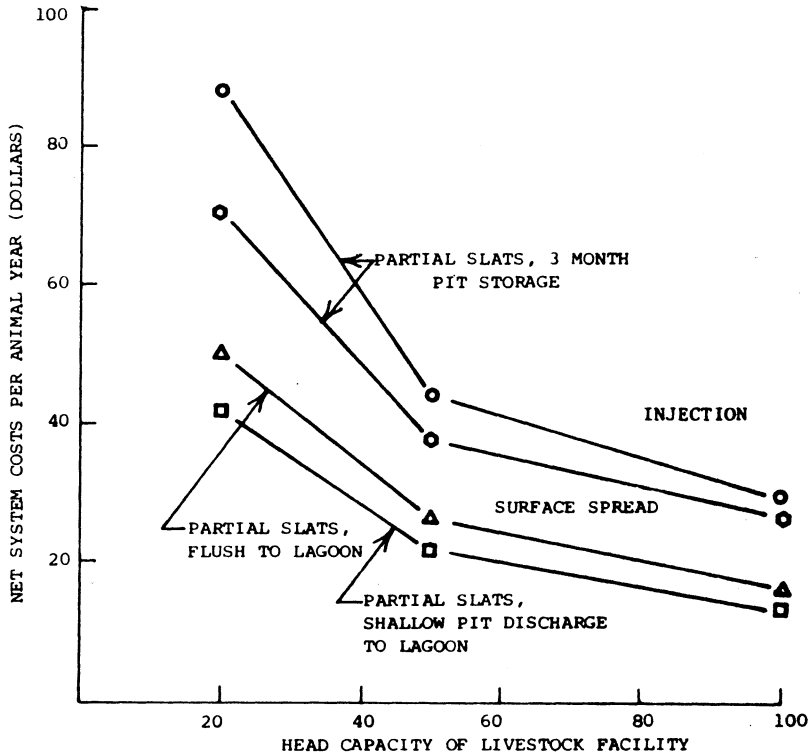

Figure 12. Swine breeding, annual net system costs for total shelter systems (100% utilization of available nutrients assumed).

Table 6. SWINE BREEDING, NET SYSTEM RETURNS AND LEVEL OF POLLUTANTS FOR ALTERNATIVE WASTE MANAGEMENT SYSTEMS

Waste Management System	System Modification	Herd Size (Head Capacity)	Net System Return: At 50 Percent Usage of Nutrients	Net System Return: At 100 Percent Usage of Nutrients	Level of Pollution[a]: Water: Quantity of Runoff	Level of Pollution[a]: Water: Quality of Runoff	Level of Pollution[a]: Odor
			(Dollars per Animal Year)		(Pollution Scale)[a]		
Pave lot with farrowing house	Base	20	-44.78	-43.68	4	4	3
	Runoff control-grass infiltration	20	-48.27	-47.17	1	1	3
	Base	50	-22.16	-21.06	4	4	3
	Runoff control-grass infiltration	50	-24.03	-22.93	1	1	3
	Base	100	-14.62	-13.52	4	4	3
	Runoff control-grass infiltration	100	-15.73	-14.63	1	1	3
Total shelter, concrete floor[b]	Base	20	-50.20	-48.80	2	2	3
	Base	50	-24.90	-23.50	2	2	3
Total shelter, partial slats, 3 month pit storage	Surface spread	20	-73.02	-71.70	2	2	3
	Injection	20	-90.79	-89.17	1	1	1
	Surface spread	50	-39.54	-38.22	2	2	4
	Injection	50	-46.48	-44.86	1	1	1
	Surface spread	100	-28.43	-27.11	2	2	4
	Injection	100	-31.75	-30.13	1	1	1

[a]Scale: 1 (No Pollution) 2 3 4 5 (Severe Pollution)

[b]Cold, cool, warm, and hot humid regions (Figure 13).

Table 7. SWINE BREEDING, NET SYSTEM RETURNS AND LEVEL OF POLLUTANTS FOR ALTERNATIVE WASTE MANAGEMENT SYSTEMS

Waste Management System	System Modification	Herd Size (Head Capacity)	Net System Return		Level of Pollution[a]		
			At 50 Percent Usage of Nutrients	At 100 Percent Usage of Nutrients	Water: Quantity of Runoff	Water: Quality of Runoff	Odor
			(Dollars per Animal Year)		(Pollution Scale)[a]		
Total shelter, partial slats, shallow pit with lagoon[b]	Base	20	-43.26	-42.67	2	2	3
	Base	50	-24.11	-23.52	2	2	3
	Base	100	-17.49	-16.90	2	2	3
Total shelter, flush beneath partial slats to lagoon[c]	Base	20	-51.15	-50.56	2	2	3
	Base	50	-27.74	-27.15	2	2	3
	Base	100	-19.83	-19.24	2	2	3

[a]Scale: 1 (No Pollution) 2 3 4 5 (Severe Pollution)

[b]Warm and hot humid.

[c]Cool, warm, and hot humid.

LEVEL OF AIR AND WATER POLLUTION FROM SWINE SYSTEMS

For fed swine lots with exposed lot surfaces, water quality may be substantially impaired due to runoff. Uncontrolled runoff from the unpaved open lot or the paved open lot produces high volumes of runoff with high concentration of pollutants as seen in Tables 2, 3, and 4, where lots with controlled runoff receive ratings of "severe pollution". Odor is also a problem on these lots. Adapting either the grass infiltration system or the detention/irrigation system dramatically improves the level of water quality. However, odor problems are unaffected.

Odor problems become less troublesome as densities on exposed lot surfaces decline. For example, all waste management alternatives using paved lot with shelter (12 sq ft per hog) receive an odor rating of "4" (Table 2), while those using the unpaved lot with shelter construction (125 sq ft per hog) receive an odor rating of "3" (Table 3), and those with unpaved lot without shelter (250 sq ft per hog) receive an odor rating of "2" (Table 4).

The total shelter, fully slotted system for fed swine is an effective method of controlling water pollution. Water quality parameters for this system are reduced to 2 in Table 5 indicating potential runoff problems only at times of field spreading manure. Odor problems become more severe, however, with the confinement system. Surface spreading of pit stored waste is often a nuisance to neighbors close by. Soil injection of pit stored wastes not only improves water quality parameters to high levels, but also reduces the odor nuisance at spreading time.

Both water pollution and odor control are adequate with the partial slats, shallow pit storage, and lagoon system for fed swine (Table 5). The only potential runoff problem occurs at the time of irrigation, and a well managed system should avoid this problem.

Water pollution and odor also are controlled well with the solid floor, flush gutter, lagoon system (Table 5). Slight water pollution occurs at the time of wastewater irrigation, thus water pollution ratings are "2".

The narrow gutter, storage basin system for fed hogs effectively controls water pollution, as seen in Table 5. Odor control problems occur when the storage basin is emptied and spreading occurs. Injection improves water quality and odor parameters to excellent levels.

The paved lot, farrowing house system for breeding swine results in water pollution control problems similar to the exposed lot systems for other species. The grass infiltration area adequately controls and discharge from this system (Table 6). Odor at the time of spreading presents a potential nuisance.

Water pollution is well controlled by confinement systems for breeding swine. For the partial slotted floor pit storage system, incorporation improves water quality and odor parameters to excellent ratings (Table 6). For the partial slotted floor systems with lagoons (Table 7), water pollution problems are negligible. Odor control is generally acceptable with confinement systems, although spreading from pit storage presents some odor nuisance unless incorporation is used.

CONCLUSIONS

A large number of swine waste management systems are available. Seventy different swine breeding and fed swine waste management system are investigated in this analysis, and many more are available but not included in the analysis.

Waste management system present significant costs for most producers. Capital investments and operating costs vary by system and by size, but generally these account for a significant portion of total costs. On the other hand, manure is a resource. There are fertilizer nutrient benefits which partially and sometimes fully offset these costs.

For fed swine, the open lot with shelter systems exhibit clear economies of size. Net system costs for the 50 animal unit lots are $10 to $30 per head while falling to near zero for the 600 or 1000 animal unit lots.

On the fed swine confinement systems, most economies of size are gained by the 600 head capacity lot. For the smaller 200 head capacity confinement system, net system costs are approximately $5 per animal unit, however, net system costs fall to nearly $0 per animal for some of the 600 or 1000 head capacity confinement lots.

For the breeding swine systems, both the open lot and total shelter systems are comparable. Net system costs total about $40 to $50 per animal unit on the 20 head capacity lots and about $20 per animal unit on the 50 and 100 head capacity lots.

Major changes in a livestock waste management system may be economically ruinous. However, most existing systems can be modified at a relatively low cost to improve environmental quality. These modifications include controlling runoff from exposed lot surfaces, controlling runoff from fields where waste is surface spread, and lessening odor nuisances from the concentrated livestock lot as well as from the field where wastes are spread.

For the producer using a system with exposed lot surfaces, the least costly changes are normally to modify the existing system to control runoff from the lot. The runoff control options available are the detention/irrigation system and the grassed infiltration system. The detention/irrigation system is the more costly alternative for the farmer, but also it improves environmental quality more than does the grass infiltration system. The small producer is at a distinct disadvantage if the detention/irrigation system is to be required. Economics of size are strongly evident with this technology. Thus, the recommended technology may be different for the small producer than the large one.

Producers with manure storage capabilities are well advised to provide for plowdown of surface spread waste or direct injection of the waste into the soil. These processes reduce potential for runoff of wastes into nearby streams and reduce odor nuisances. In addition, more of the fertilizer nutrients from the waste are available to crops. In most cases where storage is already present, these benefits from increased nutrient availability overshadow any added costs of injection or plowdown.

Waste treatment in lagoons combined with wastewater disposal by irrigation are generally effective methods of pollution control. For larger herd sizes, these systems are competitive with other waste management systems.

Those livestock producers building new facilities are well advised to consider the livestock operation as a complete system rather than considering waste disposal as an afterthought. The waste disposal method strongly affects the type of housing, the feeding system, and the profitability of the livestock enterprise.

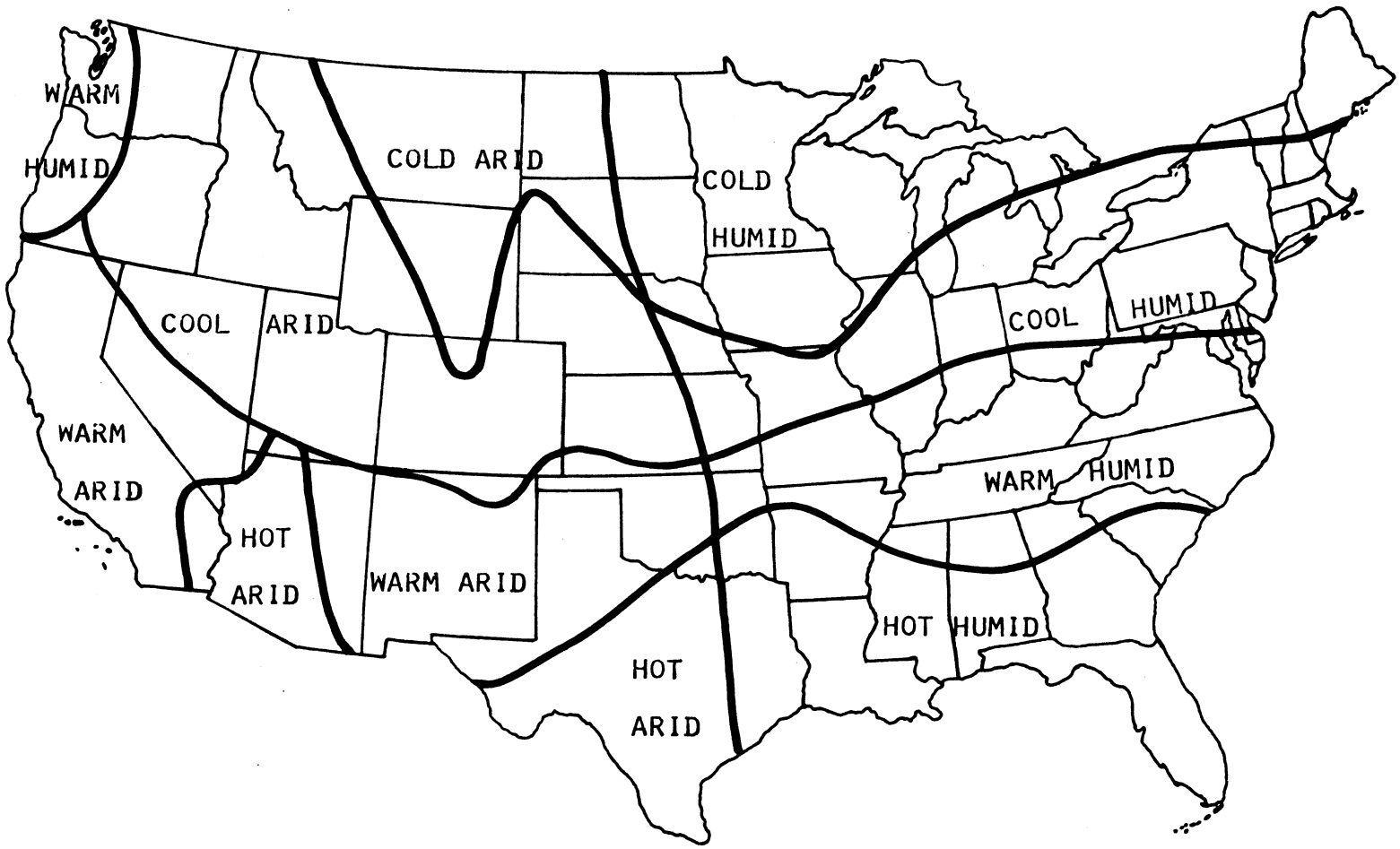

Figure 13. Climatic regions of the continental United States used for grouping similar livestock waste management systems.